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Mark St. John

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14. ABSTRACT
Tactical teams need tools to support their collaboration and to help coordinate their workflow. The HERMES solution consists of two major elements: 1) the SLATE spatial messaging collaboration tool and 2) a new concept called Workflow Coordinating Representations (WCRs) that supports task management and distributed workflow. SLATE imports mission documents, such as maps, images, and timelines, and allows users to share annotations and chat on those documents. WCRs provide a communal representation of team tasks, such as biometric analysis, where all operators can share information, and comment on the on-going activity. Phase II focused primarily on maritime interdiction tasks and how to develop SLATE concepts to support those activities. Option 1 expanded into the domain of humanitarian assistance and disaster relief (HADR). Work during the option consisted of 1) investigation of the

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spatial communication and workflow requirements of HADR and how SLATE capabilities could be adapted to these HADR requirements, 2) several design concepts for adapting SLATE to HADR, 3) a third experiment in a series to investigate good design properties of WCRs for both well- and ill-structured tasks, such as those found in HADR and maritime interdiction, 3) software developments to increase usability and port SLATE to handheld tablets, 4) a range of transition development activities. The result is a sophisticated tool with great promise for supporting small teams in maritime interdiction, HADR, and beyond, and a better theoretical understanding of small, distributed team workflow requirements and supporting technology.

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Final Report – Phase II, Option 1

Contract:	N00014-09-C-0492 SBIR No. N08.1-082 *HERMES*: Collaboration and Knowledge Interoperability in Maritime Interdiction Operations
Contractor:	Pacific Science & Engineering Group, Inc. 9180 Brown Deer Road San Diego, CA 92121
Date of report:	31 August 2011
Performance period:	9 February 2011 – 31 August 2011 – **Final Report**
Report prepared by:	Mark St. John

Work performed during the reporting period:

Abstract. Tactical teams need tools to support their collaboration and to help coordinate their workflow. The HERMES solution consists of two major elements: 1) the SLATE spatial messaging collaboration tool and 2) a new concept called Workflow Coordinating Representations (WCRs) that supports task management and distributed workflow. SLATE imports mission documents, such as maps, images, and timelines, and allows users to share annotations and chat on those documents. WCRs provide a communal representation of team tasks, such as biometric analysis, where all operators can share information, and comment on the on-going activity. Phase II focused primarily on maritime interdiction tasks and how to develop SLATE concepts to support those activities. Option 1 expanded into the domain of humanitarian assistance and disaster relief (HADR). Work during the option consisted of 1) investigation of the spatial communication and workflow requirements of HADR and how SLATE capabilities could be adapted to these HADR requirements, 2) several design concepts for adapting SLATE to HADR, 3) a third experiment in a series to investigate good design properties of WCRs for both well- and ill-structured tasks, such as those found in HADR and maritime interdiction, 3) software developments to increase usability and port SLATE to handheld tablets, 4) a range of transition development activities. The result is a sophisticated tool with great promise for supporting small teams in maritime interdiction, HADR, and beyond, and a better theoretical understanding of small, distributed team workflow requirements and supporting technology.

Humanitarian Assistance and Disaster Relief (HADR)

Pacific Science & Engineering (PSE) contracted with World Cares Center, an HADR charity based in New York, to develop concepts for adapting SLATE to HADR activities. World Cares Center developed a report that laid out a number of ways in which SLATE could be used to plan, execute, and report on HADR

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activities. These ideas included the use of maps, specialized symbology, medical forms, field report forms, and a concept of operations.

Based on these ideas, PSE developed a version of SLATE that implemented and extended many of these ideas. For example, Figure 1 illustrates the type of map and level of detail often used in HADR missions. A specialized set of relevant symbols suggested by World Cares Center was culled from MIL-STD-2525-D to populate the symbol palette. These symbols include NGOs, refugees, medical facilities, orphanages, and hotels.

Figure 1. An HADR map (left) and medical in-take form (right). HADR-relevant symbols can be dragged and dropped on the map from the toolbar on the right. A link to a picture appears in the center bottom of the medical form. Selecting the link displays a picture of the leg wound reported on the form.

A medical intake form provided by World Cares Center was reconfigured to make it more easily used in SLATE. Since SLATE uses free-hand annotations and drag and drop text boxes as input methods rather than pencil and paper, it is important to design the forms to mesh with these methods. For example, grouping vital signs into a column allows easy reporting via text box. A user can input each data point, hit return and input another data point. This design also makes the form easy to read. The benefit of using SLATE, of course, is that the information is immediately shared with other team members and headquarters. Additional forms were developed to report equipment and status of facilities visited as part of the HADR activities. The design and layout of these reporting forms was based on the results of our research to the design of forms for maritime interdiction and our laboratory studies of form design (St. John & Lacson, 2011a; St. John & Lacson, 2011b).

SLATE also provides the capability to upload and share pictures easily to document or illustrate situations. Dragging a picture file onto SLATE causes the file to be uploaded and shared with all SLATE team members. Dropping the file leaves behind a link that other users can select to view the picture. Pictures can also be uploaded as new canvases that can then be annotated like any other SLATE canvas.

The most far-reaching implication from the HADR investigation was the concept of developing methods to automatically extract information from SLATE to populate websites and databases. This extraction could concern either data developed during a mission or a whole discussion leading up to a decision. This information could be used to document and review a decision process. The automatic extraction of information from SLATE would significantly increase the efficiency of manual extraction. More importantly, it would make SLATE more interoperable with other technologies and the larger world of

HADR. This effort would be a primary focus of a Phase II, option 2 effort. See the recommendations at the end of this report for details.

Workflow Coordinating Representations experiments

Tactical teams commonly use radios and chat to communicate. While chat at least provides a permanent record that can be reviewed asynchronously, neither chat nor radio can provide the rich content and context that the teams' coordination deserves (e.g. Cummings, 2004). To provide a richer medium for workflow coordination, we recently developed the concept of workflow coordinating representations (WCRs). WCRs are based on the concept of coordinating representations or devices (Alterman, & Garland, 2001) and boundary objects (e.g., Fischer et al., 2005). One common coordinating device is the use of the word "over" during radio communications to signal the end of a conversation turn. A WCR is a coordinating representation that displays a task workflow in the shape of a communal form (St. John, 2011). Kirsh (2001) noted that "forms are another powerful coordinating mechanism in workplaces…they constrain the actions a user must consider," and they collate information into one place. Team members fill out the form as they conduct their tasks.

A WCR provides a common workspace and common ground (Clark & Brennan, 1991) for team communication and a venue for implicit coordination (Entin & Serfaty, 1999; Shah & Breazeal, 2010) since workflow is typically controlled by the state of the task rather than explicit commands. This common ground can include task information as well as collaboration information, such as task status and the current activities of team members (e.g. Carroll et al., 2003). Explicit locations for specific information help coordinate the organization and sharing of information for a set of experts. For example, the completion of one section by a team member signals task status and can be used to signal a hand-off of responsibility to another team member.

During the option, PSE designed and conducted a third experiment on the effective design of WCRs. The first two experiments were conducted during the phase II base. The first study identified and empirically tested a set of effective design properties for well-established workflow coordination tasks. The example task used was the collection and analysis of biometric data from the crew of a boarded vessel during a maritime interdiction operation. The second study investigated the applicability of those design properties to a different type of team task: ill-structured mission planning. The results indicated that the WCRs designed according to the properties were not particularly effective for the mission planning task.

The current, third, experiment was designed to further test WCR designs for the mission planning task. The rationale was that the WCRs in the prior study supported the final plan, but did not support the process of brainstorming. Perhaps if the WCR provided detailed support and structure to the process of brainstorming, it would prove more effective. Improvements to the interface were also made to make communication of plan ideas more efficient, based on comments from the prior studies.

The results rejected the process hypothesis. Rather, the better designed communication interface and WCRs were perceived by participants to better support final description and review of a plan than the initial planning process. Participants commonly believed that a free-form chat or instant message tool would provide better support for the free-roaming nature of mission planning brainstorming. The WCRs and SLATE tools require some interaction effort to use, and this effort was perceived as less worth the trouble during brainstorming. The conclusion was that the WCR designs we have been developing do provide useful structure to collaborative tasks, but they better support well-structured tasks and final results. In both cases free-form communication is more limited. When free-form communication is central to a task, then tools that have minimal interaction overhead for communication are preferable.

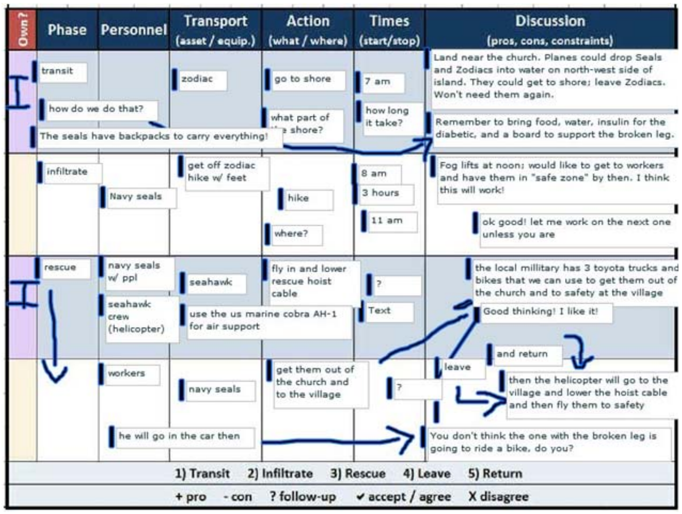

Figure 2. The Detailed-Activity WCR design from experiment 3. Each row represents an idea for the mission plan, and the columns provided structure by breaking out different content. Participants were encouraged to describe each idea by filling in the appropriate columns. Team mates could then comment, fill in additional columns, or make changes. In this way, the WCR was designed to support the process of brainstorming as well as provide structure. Nonetheless, participants preferred free-form chat.

Conclusions from the WCR experiments. Two of the most common and important tactical team tasks are coordinating the execution of team procedures and mission planning – the building up and sharing of knowledge, problem solving to develop a plan, and the review and refinement of that plan. In the first experiment, we found that a detailed WCR that matched the detail of the task and that contained a conops and symbology for the task provided useful support for coordinating the execution of team procedures. However, in the second and third experiments, we found that similarly detailed WCRs did not provide useful support for the brainstorming phase of mission planning. Instead, participants desired a chat tool. While a chat tool provides less structure to a brainstorming conversation, it facilitates the rapid and efficient exchange of ideas. A structured WCR was found to be more useful for the review phase of mission planning that follows the brainstorming phase. Together, these findings lead to refinements of our understanding of collaboration support by signaling the need to distinguish well-structured procedural tasks from ill-structured brainstorming tasks, and they further signal the need to distinguish phases of tasks, such as mission planning, that have an early brainstorming component followed by a more structured review component. Different tools support these different tasks and phases of tasks, and a successful collaboration tool must provide the right support during each phase.

A report of experiment 3 was written, and it is a deliverable for the SLATE phase II option. Additionally, the manuscript reporting the first two experiments was accepted for presentation at the Human Factors and Ergonomics Society national meeting. A final, published version of the manuscript was completed and delivered to the society, and a presentation was developed. The revised manuscript is a deliverable for the SLATE phase II option.

Software

Several improvements were made to the software based on the results of the experiments described above. The goal was to improve the software to provide support the range of tactical team tasks, namely, for both well-structured procedural tasks and ill-structured mission planning and brainstorming tasks. Since support for procedures and WCR was the focus of the phase II base period, the option focused on support for brainstorming.

Brainstorming and chat. First, several improvements were made to the chat tool embedded in SLATE. Many participants commented that they wanted a chat tool. Since SLATE has a chat tool, we interpreted this comment to mean that the current chat tool was not sufficiently obvious or easy to use. We moved the chat input box to the bottom of the screen, which is more typical of commercial chat tools, and we changed the design to look more like a typical chat input box. We also created a toggle that allows the text messages associated with all infobs to be displayed in a column at the same time. This design still fits within the SLATE-infob metaphor, but it looks more like a typical chat window in which all chat messages can be read simply by moving one's eye. Previously, access to the text messages required users to roll over infobs and view the texts as tool tips. While this method reduced clutter, it required more effort from the user. We believe these changes to the chat tool created a more functional and appealing tool.

We also developed an undo command that erases one annotation or symbol at a time. Previously, users could erase an entire draft message, but this undo command provides finer control of message composition.

Another new feature was color coding each user's annotations. Many test participants have commented that color coded annotations might help users understand who drew which graphics. Our hesitation, from the beginning of the project, was that the colors might be misconstrued with military affiliation, e.g. red for hostile. However, many domains do not have a strong affiliation component, and most of the annotation colors do not map to MILSTD colors. Therefore, we decided to implement this feature.

We also implemented several subtle improvements to make finding and displaying new messages more efficient. Since users can reply to any infob, new messages sometimes occur high in the infob column rather than appended to the bottom of the column. This reply capability is important for some conversational threads, but it can make finding new messages awkward in some circumstances. A vertical "message summary" bar was added next to the infob column. It indicates the location of new messages in the infob column. The message summary bar provides a clear visual way to see the locations of new messages. The message summary bar is also color coded by user. Additionally, a "next" infob button was added to allow users to quickly click through new messages. Clicking the next button scrolls the infob list to the chronologically oldest new infob and displays any text and graphics.

HADR and interoperability. As part of the investigation of HADR effort during the option, we also investigated methods of making SLATE more interoperable with other devices and websites. One capability that World Cares Center suggested was the ability to extract a sequence of messages from SLATE for later review and documentation in other software applications. This capability, for example, would allow users to review how a decision was made and what led up to it. Of course, users could use SLATE to review a sequence of messages, but the new idea was to upload the messages to a website for use in other applications. Extracting the sequence of text messages is not difficult, and we had already built the ability to publish a canvas, complete with all annotations as an image. However, it is difficult to map the texts to the annotations. In fact, solving this mapping issue is one of the core rationales for

SLATE. Our approach here was to number each infob and then apply that number to the text and each graphic associated with that infob. The result is a text file containing a sequence of numbered text messages, and an image of the canvas in which each annotation line or symbol has a small number displayed next to it. The text file and image could then be uploaded to a website for review and analysis in many different applications. Numbering the annotations is also useful for mapping back from the canvas to the infob list and associated texts, similar to the color-coding of user annotations described above. Because the numbers on the annotations can cause clutter, we developed a toggle that allows users to turn the numbers on and off, as desired. This capability is the first among many capabilities we have planned to improve the interoperability of SLATE.

A major effort was undertaken to make the exchange of messages more robust to momentary network outages and connectivity problems. A master list of messages was developed for the SLATE server to maintain and check against each team member's list of messages. If discrepancies are found, the server sends the missing messages.

We also investigated porting SLATE to several handheld tablet platforms in order to illustrate in a concrete way how SLATE can be taken into the field on small mobile devices. We investigated several current Android platforms and a current Windows 7 platform. We ported SLATE to a Hewlett Packard "SLATE 500". This tablet has a 9" screen, is touch sensitive by both pen and finger, and fits into a large cargo pocket, such as a Marine Corps technical uniform pants pocket. The software ported easily to this Windows 7 platform. The platform also contains a built-in camera that can be used interactively with SLATE to take and share pictures of situations. The interface was redesigned in several minor ways to adjust it to the screen resolution and ratio of height to width. Because the pixels are closer together, several buttons and menus in SLATE were redesigned to be larger and easier to access by finger. The result is a highly useable, mobile version of SLATE.

Transition activities

A number of activities were conducted to work toward transitioning SLATE.

- Attended the CKI ONR workshop, and discussed the project with program management and other researchers. Developed a brief that focused on the scientific rationales for the design, the scientific issues the project addresses, and accomplishments.
- Developed a transition brief that focuses on the features and capabilities of SLATE. Developed a seven minute narrated movie to illustrate SLATE functionality. Used in conjunction with the brief, it makes an effective introduction to SLATE. The demonstration movie is a deliverable for the project.
- Met with the Navy TAP project "coach" to discuss the marketing analyses they had performed on behalf of SLATE. Then called and meet with industry and government contacts that were developed through the marketing analysis. In particular, meet with representatives from Northrop Grumman's TIGR program and contacted several Army programs.
- Travelled to Monterey, CA to attend an NPS workshop on maritime interdiction. In addition to meeting with Alex Bordetsky and his team, met other attendees from Homeland Security including the Domestic Nuclear Detection Office. Followed up with those individuals to discuss transition opportunities.
- Met with Army representatives developing a handheld GPS tool and briefed them on SLATE team collaboration capabilities.
- Developed concepts for transitioning SLATE to emergency medical services in conjunction with Dr. Emily Patterson from Ohio State University. The concept is to provide SLATE to dispatchers,

EMS technicians in the field, and hospital emergency department nurses. SLATE would allow much tighter coupling and situation awareness among these team members than current technology allows.
- Met on several occasions with DefenseWeb, a medical informatics company. Because they are a division of Humana, there a numerous opportunities to adapt SLATE to medical applications. We are currently working with them to develop appropriate briefing materials to coordinate with their business development team.
- Discussed SLATE capabilities and future directions with Dr. Rebecca Goolsby at ONR. There are interesting and promising opportunities for SLATE in the HADR realm. SLATE appears to be very well suited to work in combination with other situation awareness tools being developed for the HADR community. SLATE is also well suited to the open source, small team characteristics of many HADR field operations, and it can potentially interoperate with other tools better suited to large enterprise coordination. HADR, therefore, is a very promising area for further SLATE development and transition.

It is clear from these discussions that SLATE continues to offer distinct differences from and advantages over alternative software for supporting tactical team collaboration. For example, the TIGR program focuses on compiling intelligence information into a geospatial database. While conversations among users are supported, the support is designed to focus around locations and intelligence data. SLATE, on the other hand, focuses on the planning and execution of missions. It offers an effective mix of mobility, interruption recovery, and multi-mediate tools. It is much more oriented toward team communication and coordination throughout a mission. TIGR and SLATE are therefore more complementary than they are competitive.

While the utility of SLATE is clear and users are enthusiastic in a number of domains, it remains difficult to find government or commercial programs at the right stage of development where SLATE concepts or software can be effectively transitioned. Based on our observations, the most likely stage for transition is early in a program during the definition of requirements and early concept development. SLATE capabilities and the expertise in tactical team collaboration that the project has garnered could be profitably applied to guide early-stage programs to consider capabilities and designs that will lead to successful collaboration support. SLATE could thereby transition either whole-clothe or as a useful set of concepts to be incorporated into other tools. Either result would benefit collaboration technology and tactical team collaboration.

Finally, while not a transition out of SLATE into other tools, it is important to note that there have been numerous important transitions of ONR-funded research and concepts into SLATE. In particular, the design of the interruption recovery concepts in SLATE was heavily influenced by Science and Technology research supported by ONR code 341. Additionally, the design of SLATE's method for integrating text and graphics was heavily influenced by the research conducted under the Knowledge Interoperability program in ONR code 341.

Recommendations

Our first recommendation is to exercise the phase II, option 2 of the SBIR in order to further develop SLATE for the HADR domain. Support for HADR is particularly promising because of the mix of spatial and workflow tasks that SLATE supports. Among workflow tasks, there are both procedural tasks well supported by SLATE WCRs and brainstorming tasks well supported by SLATE's revised chat tool. Further, the work during the current option 1 to identify interoperability requirements and to conceptualize solutions will lead to quick advances in concepts and developments. ONR's HADR program is building a suite of tools and concepts that SLATE can easily fit into and contribute to by providing important new capabilities.

In more detail, option 2 would focus on interoperability with HADR. One thrust would be developing methods to extract text and graphics data from SLATE and make it available to other applications. One important use would be for sending SLATE texts and graphics to cell phones so that team members without SLATE or with limited connectivity can participate and share information with the rest of a team. Another use would be for posting SLATE data to shared websites where it can be exploited and preserved and to other applications.

A second thrust for interoperability developments will be to connect SLATE to electronic databases. The idea is that SLATE messages could be used to input data into shared electronic databases, such as medical records and HADR planning tools, as well as allowing SLATE users to see database cells that are of interest to them.

A second recommendation is to continue to interact with NPS and their MIO group, looking for opportunities for field testing and transition within the MIO domain. There is clear utility and interest in SLATE in this domain, and the NPS program is an effective way to remain engaged.

A third recommendation is to continue to look for other government programs developing communication and collaboration tools for tactical teams. As noted above, it appears that the most effective point for transition and cross-fertilization is during the early stages of requirements development.

Deliverables

St. John, MF & Lacson, FC (2011). Supporting brainstorming activities among tactical teams. Technical report. San Diego, CA: Pacific-Science & Engineering Group.

St. John, MF & Lacson, FC (2011). An exploratory study of workflow support for tactical teams. In *Proceedings of the Human Factors and Ergonomics Society 55th Annual Meeting*. Santa Monica, CA: Human Factors and Ergonomics Society.

St. John, MF (2011). SLATE demonstration movie. Movie. San Diego, CA: Pacific-Science & Engineering Group.

Breakdown of contract costs (phase II base and option 1 combined)

Labor	542,610.62
Participant fees	3,265.00
Consultant	4,000.00
Travel	9,205.38
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Electronic Distribution

Tracy Frost, SBIR Program Manager, frostt@onr.navy.mil

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Jeffrey Morrison, ONR Program Manager, Jeffrey.g.morrison@navy.mil
Ranjeev Mittu, ONR Program Manager, mittu@itd.nrl.navy.mil
DTIC-OA (SBIR), AQ@DTIC.mil
Director, Navy Research Lab, reports@library.nrl.navy.mil

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